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ENGINEERING AND SCIENTIFIC RESEARCH AT WES, MARCH 1973.(U)
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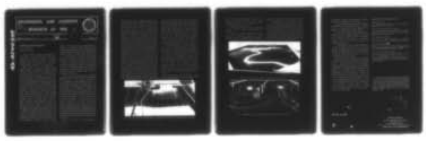

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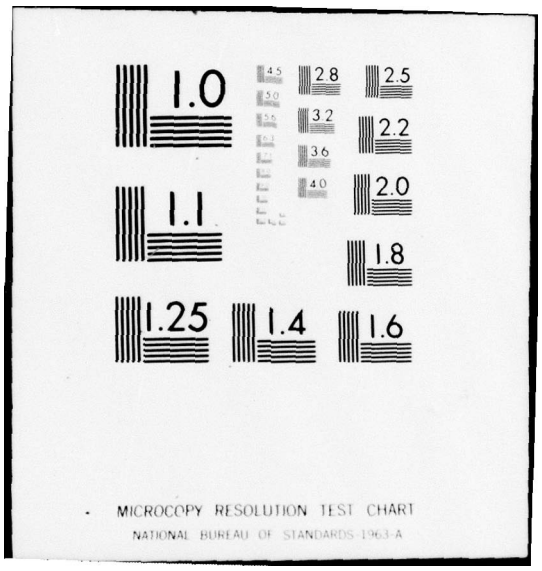
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ENGINEERING AND SCIENTIFIC RESEARCH AT WES

Miscellaneous Paper 0-73-3

March 1973

WATER QUALITY RESEARCH,

by J. L. Grace, Jr.
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Effective planning, design, and management of man-made lakes for optimum utilization of water involve, among other factors, the problems of predicting, monitoring, and controlling the physical, chemical, and biological quality of impounded waters and releases through spillways, powerhouses, and outlet works.

During 1966, the Corps of Engineers initiated laboratory research at the Waterways Experiment Station (WES) to determine the characteristics of withdrawal zones resulting from release of flows through orifices and over weirs from randomly stratified lakes. It was considered that any practical method for predicting the quality of water discharged through an outlet should be based on the extent of the zone of withdrawal and the distribution of velocities and flow therein. Then, if the vertical distribution of one or more water quality parameters is known from actual monitoring of the reservoir upstream of the regulating structures, the resulting value of each parameter in the release could be computed by means of a simple weighted average of the known parameters and the predicted distribution of flow. The results of completed and current generalized research and specific project studies are summarized herein to indicate the present state-of-the-art relative to physical and mathematical simulations of reservoir water quality. Efforts to be initiated in the immediate future are mentioned to indicate the improved and additional techniques anticipated within a few years.

Results of completed physical simulations and analyses for describing both the vertical extent and distribution of flow within a zone of withdrawal from a randomly stratified reservoir are available for predicting the selective withdrawal characteristics of single or multiple orifices as well as those of free or submerged weirs. In addition, a computer program entitled "SELECT" has been developed and is available for both batch and time-sharing modes of analyzing simultaneous multiple outlet operations involving as many as six outlets; the top outlet may be a free or submerged weir, if required. These generalized results and the computer program are recommended for application to determine the actual scheme of operating or managing a given project structure to obtain desired downstream objectives. They also have been incorporated to refine certain available mathematical simulations for predicting and controlling budgets of both physical and conservative chemical constituents within, as well as downstream of, reservoirs.

The results of generalized physical simulations conducted for and reported in Research and Development Progress Report No. 714 of the Office of Saline Water, U. S. Department of Interior (available from the U. S. Government Printing Office), merit mention relative to the general subject of the mechanics of density-stratified flow and specifically to the management of relatively dense waste waters discharged into a flowing ambient stream. The report reveals that a multiport diffuser yields two to five times greater initial dilution than a simple pipe outfall, and also presents dimensionless means of predicting the three-dimensional geometry of the resulting plume and maximum concentrations of physical and conservative chemical constituents in both the near and far field. Numerical simulation and design considerations of outfall systems for desalination plants have been developed by the Dow Chemical Company and Texas A&M University based on these generalized results. It is recommended that similar applications be made for analysis, design, and management of environmentally acceptable systems for disposal of dense waste waters.

Since it is impossible to accurately distinguish or

predict the actual selective withdrawal characteristics of projects involving complicated geometries of approach and intake structure design, a number of specific project structures have been investigated since 1966. Some of the most interesting results of these studies are briefly summarized as follows. The study of Meramec Park Reservoir and Outlet Works indicated that the interface between the epilimnion and hypolimnion waters of a stratified reservoir is elevated and lowered, respectively, along the inner and outer portions of a curved approach channel and that considerable mixing of these waters may occur due to shear generated along the interface in a narrow channel. Model study of the submerged water quality weir proposed upstream of the Clarence Cannon Dam spillway and pumped storage power generating facilities (fig. 1) indicated that a considerable length of weir located an appreciable distance upstream of the main dam was required to permit release of only epilimnetic water during periods of generation and to prevent destratification of the reservoir during pumpback operations. Study of the water quality tower proposed for Rowlesburg Dam indicated that the close proximity of the tower to the left abutment caused considerable contraction of flow approaching the spillway and that a submerged slot or relatively wide orifice of limited height was more effective than a free weir in releasing epilimnetic water of the quantity desired. Study of the multilevel intake structure proposed for Lake New Hope indicated that an inlet located on the upstream face of the structure would permit releases approximately double those permitted through a side face inlet located close to the embankment without initiating withdrawal of hypolimnion waters. Investigations of the low-flow water quality conduits of Beltzville and Fort Scott Outlet Works indicated that the regulation gate should be located downstream of the entry and normal to the conduit and that only open channel flow should be permitted downstream of the regulating gate by providing appropriate air vents and either a roof offset in the conduit or a restriction of the gate opening to prevent severe reduced pressures and the likelihood for cavitation damage.

A specific project study has just been completed at WES to develop a mathematical model for simulation of temperatures and turbidities observed in the existing Hills Creek Reservoir and in regulated releases therefrom, as well as for prediction, evaluation, and design of the proposed Lost Creek Reservoir and Multilevel Outlet Works. The mathematical model termed "WESTEX" is available in both batch and time-sharing modes and may be used for analysis of both physical and conservative chemical constituents.The effect of various geometric designs and operational schemes of the reservoir and regulating structure on these constituents may also be analyzed and revised as needed to ensure that desired objectives may be obtained.

The currently active physical simulation of the proposed Beech Fork Reservoir and Outlet Works at WES

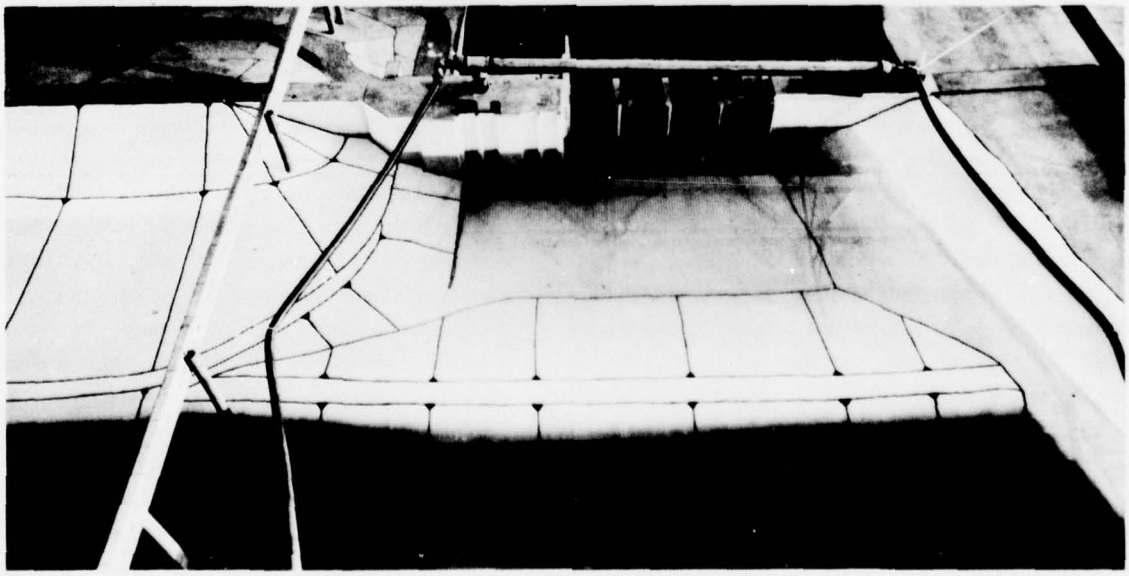

Fig. 1. 1:50-scale model of water quality weir, spillway, and powerhouse for Clarence Cannon Reservoir

(fig. 2) is concerned with investigation of density currents within the reservoir and verification of the selective withdrawal characteristics of two alternative locations of the multilevel intake structure (fig. 3).

Currently active generalized research in existing WES facilities is concerned with the following subjects and objectives:

1. Mechanics of Density-Stratified Flow in Lakes and Rivers—to physically simulate and develop mathematical means of describing inflow characteristics similar to those available for describing outflow as well as the overall hydrodynamics of stratified lakes and rivers.

2. Methods of Enhancing Water Quality in Lakes and Rivers—to physically simulate and evaluate hydraulic means for partial and total destratification of reservoirs and for inducing circulation to increase the waste assimilative capacity of sluggish streams, and to develop mathematical means for analysis, plan, design, and operation of effective systems. Similar efforts will be devoted to developing effective means for aeration of anaerobic hypolimnions and

Fig. 2. 1:36-scale model of Beech Fork Reservoir and Outlet Works

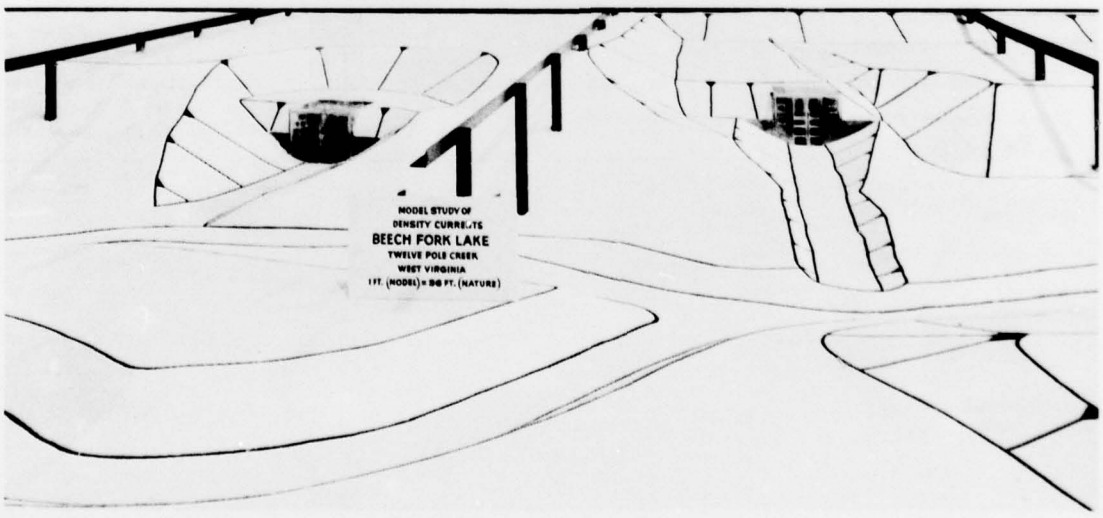

Fig. 3. Alternative locations of multilevel intake structure; Beech Fork Reservoir

low DO reaches of rivers and to general study of reaeration characteristics of spillways and outlet works.

3. Water Quality Intake Structures—to investigate and describe selective withdrawal characteristics of orifices and slots in sloping and horizontal planes, and the mechanics of density-stratified flow in manifolds.

4. Prediction and Control of Water Quality in Lakes and Rivers—to assess available techniques and develop refined appropriate mathematical means for simulating, analyzing, designing, and managing one or a system of multipurpose water resource projects to achieve desired environmental objectives.

5. Field Review of Water Quality Problems—to exchange information between research and other personnel for identification of water quality problems existing in the field and the needs of various offices so that research and development activities can be directed to appropriate and timely solutions.

Construction of a new building is to be completed at WES this FY which will house facilities to be installed during FY 74 for future investigations that will permit physical simulation and study of meteorological, hydrological, operational, physical, chemical, and biological characteristics on a typical unsteady and varied basis. Obviously, as additional and new knowledge and understanding of the various physical, chemical, and biological phenomena are obtained from the current and future research findings, appropriate development of better and new mathematical simulations will follow to provide ready and adequate analysis, plan, design, and management of environmentally compatible projects to achieve improved social and economic benefits and at least maintain and hopefully improve our present standard of living in the United States.

REPORTS RECENTLY PUBLISHED BY WES

Hydraulics Laboratory:

Wave Transmission Through Rock Structures, by G. H. Keulegan, Research Report H-73-1, Feb 1973.

Mobility and Environmental Systems Laboratory:

Overt Ecologic Effects of Ejecta from Nuclear Excavation, Proposed Interoceanic Canal Route 25, by E. E. Addor and H. H. Allen, Miscellaneous Paper M-72-9, Dec 1972.

Soils and Pavements Laboratory:

State-of-the-Art of Marine Soil Mechanics and Foundation Engineering, no author listed, Technical Report S-72-11, Aug 1972.

Weapons Effects Laboratory:

Protection of POL Storage Facilities, Proposed Expedient Underground Storage Facility, by L. Miller, F. W. Skinner, Jr., and C. E. Stewart, Miscellaneous Paper N-73-1, Jan 1973.

Explosive Excavation Research Laboratory:

Project Tugboat; Explosive Excavation of a Harbor in Coral, by W. C. Day, Technical Report E-72-23, Feb 1972.

Estimating Water-Shock-Induced Airblast from Detonations in a Medium Overlain with Water, by C. M. Snell, Technical Report E-72-16, Apr 1972.

Engineering and Scientific Research at WES is published by the Waterways Experiment Station (WES), Vicksburg, Mississippi, to acquaint U. S. Government agencies and the research community in general with the many-faceted types of engineering and scientific activities currently being conducted at WES. Inquiries with regard to any of the reported specific subjects will be welcomed, and should be addressed to respective authors, U. S. Army Engineer Waterways Experiment Station, P. O. Box 631, Vicksburg, Mississippi 39180.